UTAH GEOLOGICAL AND MINERAL SURVEY

REPORT OF INVESTIGATION

NO. 203

GEOLOGIC EVALUATION OF A PROPOSED LANDFILL SITE IN WEBER COUNTY, UTAH

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Geologic Evaluation of a Proposed Landfill Site in Weber County, Utah

PURPOSE AND SCOPE

In response to a request from Roger F. Rawson, Chairman of the Weber County Commission, a geologic evaluation was made of a proposed landfill site in western Weber County. The landfill is to be patterned after the existing Salt Lake County landfill, with some modifications. Refuse cells of the proposed landfill are to be constructed above shallow ground-water levels and lined on the top, bottom, and sides with impermeable clay. Individual cells will protrude above the ground surface, giving a mound-like appearance to the landscape, and will be separated by surface ponds (Kelley, 1985). The landfill is expected to meet solid waste disposal needs of Weber County for the next 100 years (Kelley, oral commun., Sept. 27, 1985).

The role of the Utah Geological and Mineral Survey (UGMS) in the siting of landfills is one of professional recommendation based on past and current geological evidence, and on plausible future geologic and hydrologic conditions. These factors are evaluated in this report, then compared to existing landfill regulations and requirements as outlined by the Utah State Department of Health. The scope of work includes a review of available published and unpublished literature, reports, maps and well logs, analysis of aerial photographs, and two site visits involving a surface reconnaissance (Sept. 27, 1985) and excavation and logging of four test pits (Oct. 2, 1985). Present during the first visit were Kenneth Bradshaw, Executive Director of the Department of Aging and Volunteer Services for Weber County, and Charles Kelley of the Weber County Solid Waste Task Force. Present during the second visit were Max Hunter of the Weber County Roads Department, and Charles Kelley.

LOCATION AND SITE CONDITIONS

The area considered for the landfill is located near the Great Salt Lake in T. 6 N., R. 3 W. SLB&M (figure 1). It comprises approximately 4,200 acres and is bounded on the north by the Southern Pacific Railroad, on the east by the Weber River, and on the south and southwest by the Ogden Bay Waterfowl Management Area (OBWMA) and the North Fork of the Weber River. The southern periphery of the site below 4,215 feet elevation is inundated in places by recent encroachment of the Great Salt Lake. Greater than average precipitation during 1982-1984 has caused this flooding as well as breaching of levees surrounding the OBWMA and North Fork of the Weber River. Although the entire 4,200 acres is slated for purchase, only land above 4,215 feet elevation (approximately 2,400 acres) would be used for the landfill (Kelley, oral commun., Sept. 27, 1985). This area includes portions of sections 24, 25, and 26 which are designated as the primary disposal area (figure 2).

The site is relatively flat with only minor surface undulations. Total relief is 13 feet, with elevations ranging from approximately 4,221 feet in the northern portion of section 23 to 4,208.50 feet (Great Salt Lake level on September 15, 1985) (Alder, 1985) in the southwestern portion of section 28 (figure 2). The site contains numerous perennial and ephemeral ponds, and intermittent streams and canals that drain southward into the North Fork of the Weber River. Extensive marshy areas (mud flats, relict river channel

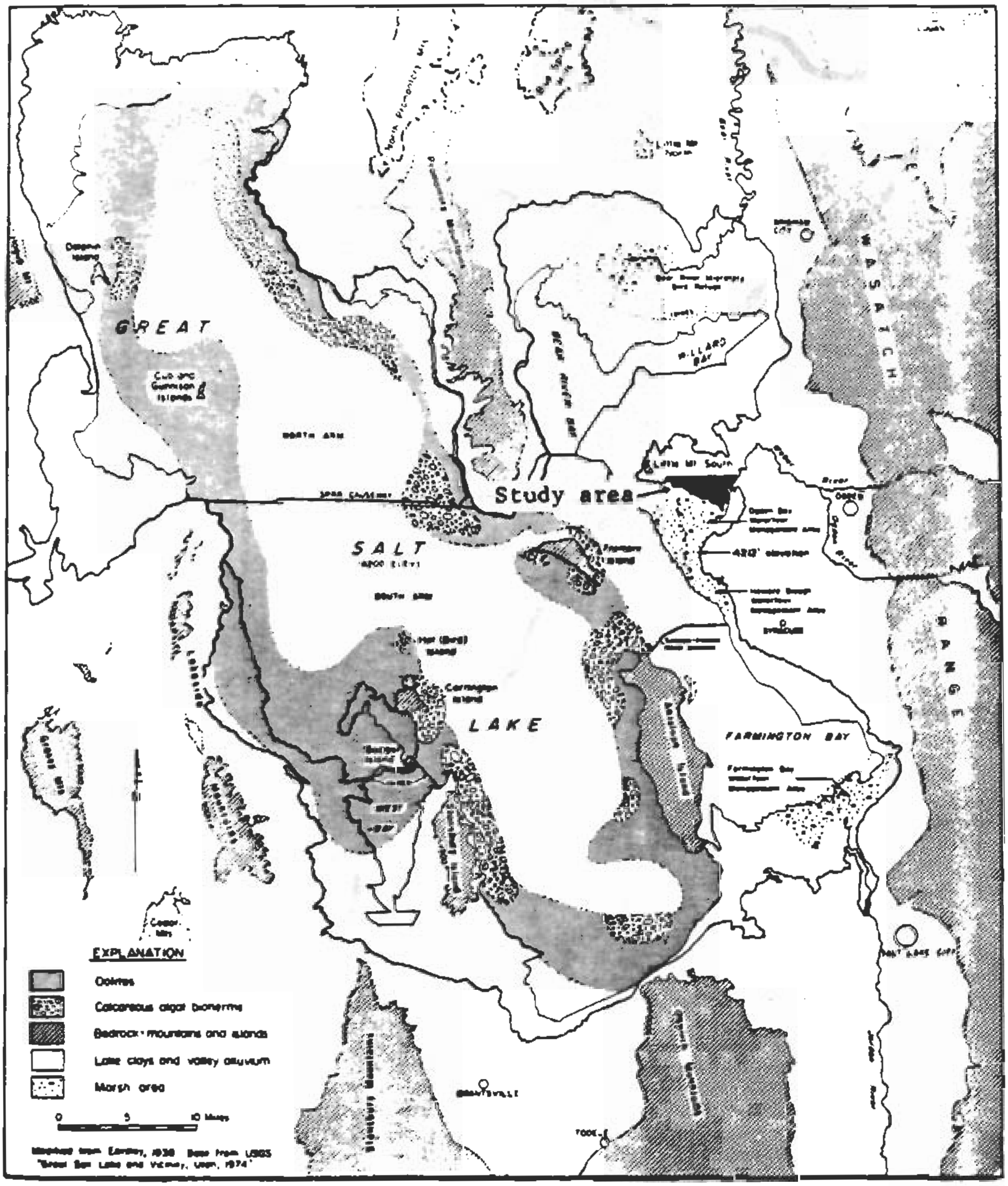


Figure 1. General location map, proposed landfill site (after Gwynn and Murphy, 1980).

Base map from USGS topographic 7½' quadrangle, Ogden Bay, Utah

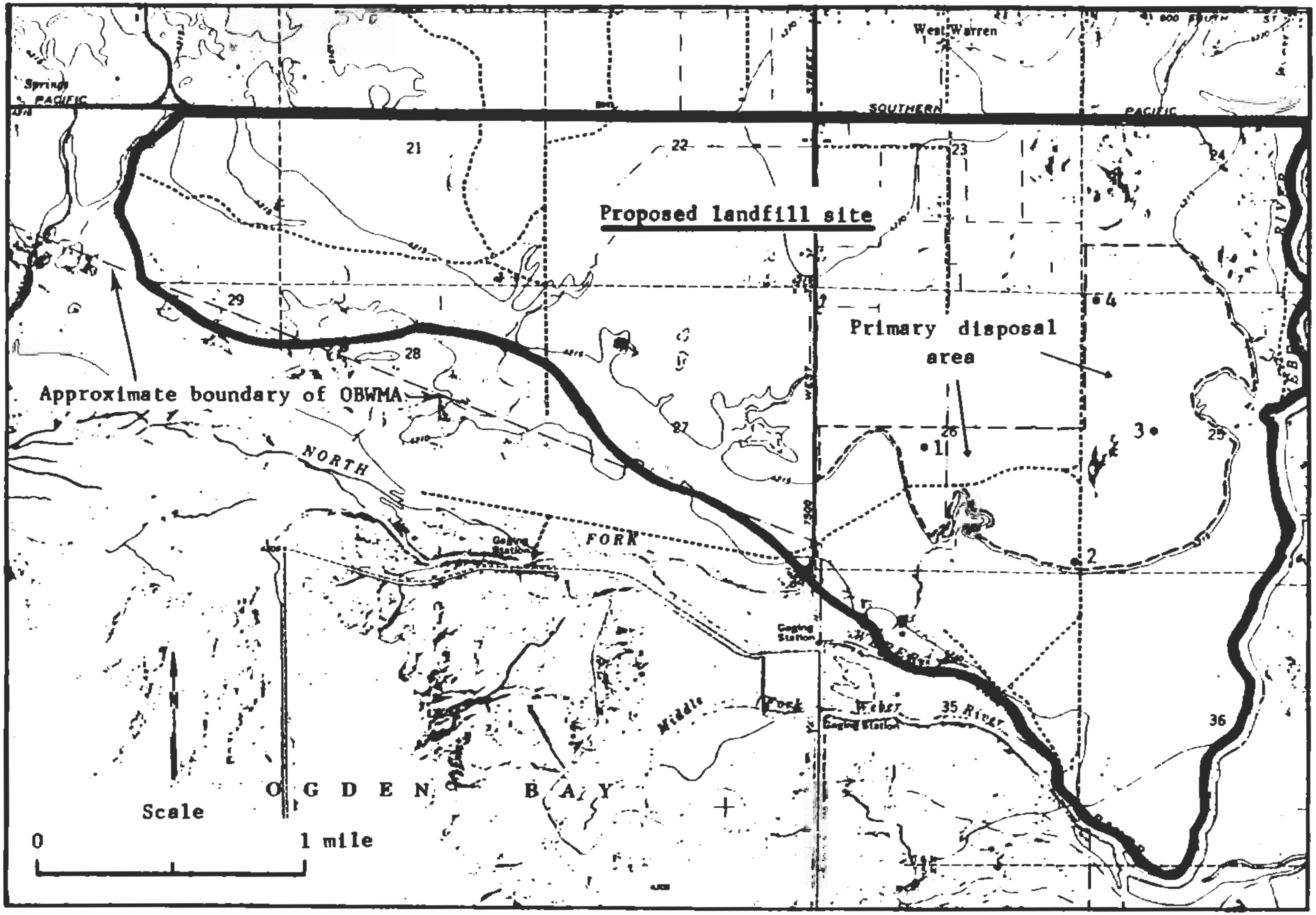


Figure 2. Proposed landfill site showing primary disposal area and test pit locations.

scars, and oxbow lakes) are present in the eastern portion of the site (sections 24 and 25) west of the Weber River (figure 2). Standing water in this area is prevented from draining into the Weber River by a 5 to 6 foot levee paralleling the river.

Low-lying swamps in the southern portion of the site contain abundant marsh grasses and other vegetation that thrives under brackish conditions. Farther north, in sections 22 and 23 and in the northern part of section 26 and northwestern part of section 25, sagebrush and short grasses are common. The land is mainly used for cattle grazing; crop production is limited by the high alkaline and salt content of the soils.

GEOLOGY AND SOILS

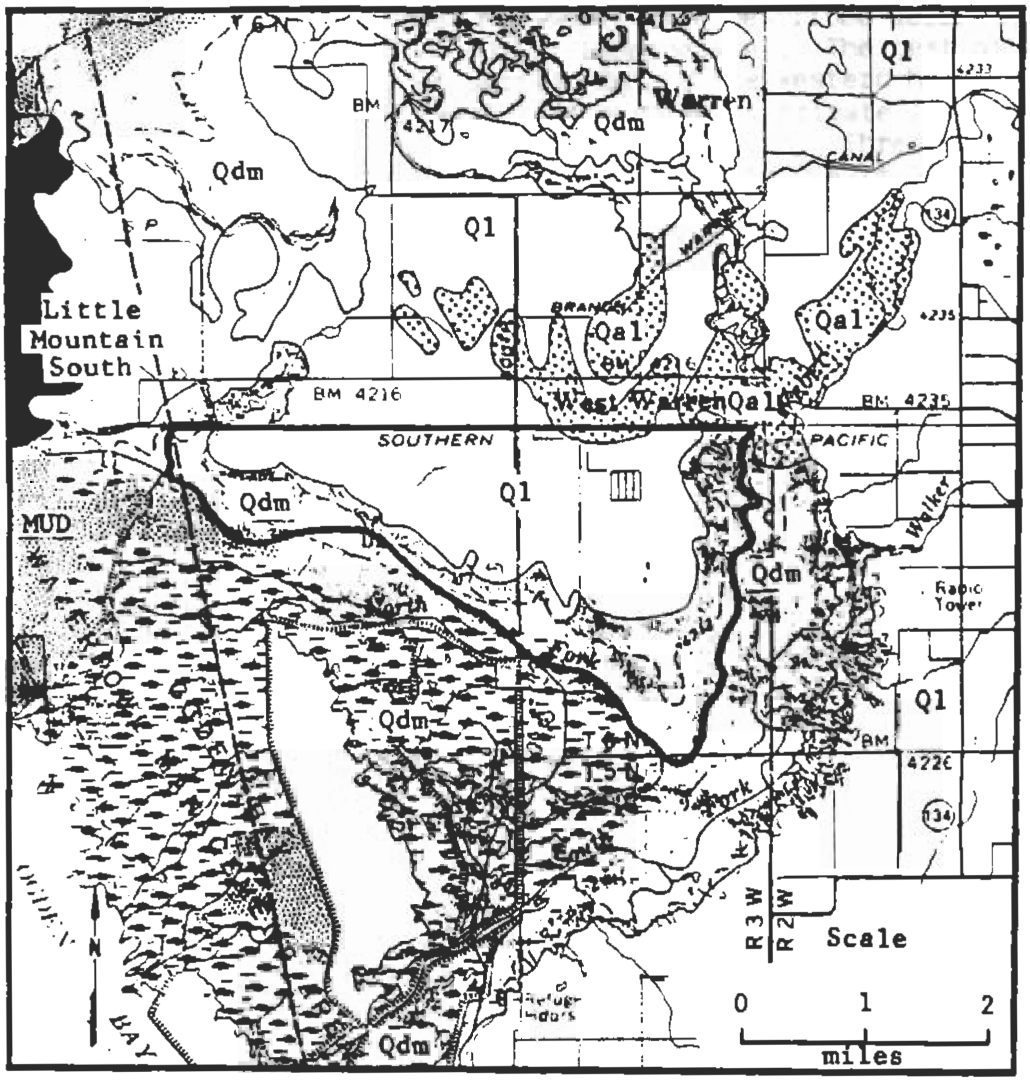
The site lies on an extensive lowland plain formed during the Quaternary Period by deposition of ancient Lake Bonneville and Great Salt Lake sediments in combination with delta deposits from the Weber River (Feth, 1955). These deposits are generally unconsolidated or semi-consolidated (Smith and Gates, 1963; Feth and others, 1966). The southern one-third of the site and that portion adjacent to the Weber River contain geologically recent, poorly-drained silt and clay (Qdm) deposited by Lake Bonneville and the Great Salt Lake (figure 3). These deposits are approximately 10 feet thick, fetid, salt-impregnated, and cover the area to an elevation of about 4,213 feet (Eardley and Gvosdetsky, 1960; Feth and others, 1966). The majority of the landfill site including the primary disposal area is covered by lacustrine deposits (Ql) composed of clay, silt, and sand (figure 3). These deposits attain a thickness of approximately 35 feet and cover much of the land surface between 4,210 and 4,300 feet elevation (Feth and others, 1966). Within the confines of the proposed landfill, the surface Ql deposits are composed primarily of low-permeabilty, salt-impregnated clay. Alternating beds of clay and well- to poorly-sorted sand underlie the surface clay. Alluvial silt and sand deposits (Qal) from river and stream channels are present in the northern part of the landfill site and crop out more extensively farther north and northwest of the landfill boundary (figure 3).

Soils at the landfill site consist of the Leland-Payson-Warm Springs association, which are generally poorly-drained, salt alkali, fine sandy loams (Erickson and Wilson, 1968). Soil types within the landfill's primary disposal area fall into one of three categories with the following characteristics:

Warm Springs fine sandy loam: somewhat poorly drained, strongly alkali, occurs mainly in slight depressions, depth to water table commonly 24 to 40 inches.

Lakeshore fine sandy loam: poorly drained and very poorly drained lake terraces. Salt content high, occurs in slight depressions on low lake terraces, water table is at or near the surface most of the time.

Leland silt loam: somewhat poorly drained, strongly affected by alkali and moderately to strongly affected by salts; occurs on broad, smooth to undulating low lake terraces, depth to water table 48 to 60 inches, distinct mottles are common below depth of 24 inches.



EXPLANATION

Q1	Lacustrine deposits, including clay, silt, and sand.
Qal	Low-level alluvial deposits of flood plains and channels, mostly silt and sand.
Qdm	Marsh or shallow lake deposits in deltaic settings; includes salt flats, poorly-drained soils with high silt and clay contents.

Figure 3 Surficial geologic map of proposed landfill and surrounding area (modified from Davis, 1985).

Four test pits were excavated within the primary disposal area of the proposed landfill (figure 2). Test pit soils were described according to the Unified Soil Classification System (USCS) (appendix A). The test pits were restricted to the southern half of section 26 and the western half of section 25, areas where permission to excavate was granted by private landowners. All test pits were located on or above 4,215 feet elevation. Three test pits were excavated into Leland soils, the other (test pit 2) into Warm Springs soil.

The test pits all showed similar soils, with predominantly lean (silty) clays (CL) extending 3 to 4 feet below the ground surface (appendix B). All test pits had stage II caliche development at depths varying between 0.6 and 1.7 feet. Caliche is commonly formed by downward leaching of carbonate from overlying soil by infiltrating precipitation, but it may also form by carbonate precipitation above a shallow water table. The latter theory is supported by the presence of extensive soil mottling in the clay and sand units underlying the caliche zones (appendix B). Such mottling is indicative of a fluctuating water table.

The depth of test pit excavations was limited to a maximum of 6.2 feet (test pits 1 and 2, appendix B) by ground water in a poorly-graded pervious sand unit (SP) encountered 3 to 4 feet beneath the ground surface. Water is perched above a clay layer (CL) of unknown depth. Evidence for the existence of the mottled, gray clay unit was seen in the spoil piles where the last few buckets of soil were placed. Numerous well logs drilled in sections 22 and 23 indicate alternating sequences of clay and sand reaching to depths of at least 600 feet below the ground surface.

FAULTS

The main trace of the north-south-trending Wasatch fault is located approximately 9 miles east of the landfill site. In addition, Stokes (1963; 1980), using 1961 unpublished data supplied by Eardley, shows three geophysically inferred faults, one of which lies 7 miles east of the landfill site. The remaining two trend north-south and traverse the site through sections 24 and 25, and 22 and 27 respectively (figure 4). Feth and others (1966) depict an inferred north-south-trending fault crossing the extreme western part of the proposed landfill through section 20. Evidence for this fault was inferred by the presence of a series of warm springs rising to the surface in a somewhat linear pattern. Numerous other pre-Quaternary faults have been mapped west of the site in the Promontory Mountains (Olson, 1956). Except for the Wasatch fault, none of the faults mentioned have shown movement during Quaternary time, and none of the inferred faults crossing the site show evidence of surface rupture.

HYDROLOGY

Ground Water

The proposed landfill lies in a ground-water discharge zone characteristic of areas adjacent to the Great Salt Lake. Ground-water flow moves by gravity from the Wasatch Mountains toward the Great Salt Lake under artesian conditions in deep aquifers and as unconfined shallow ground water. Two artesian aquifers, the Sunset and Delta, have been identified in the area

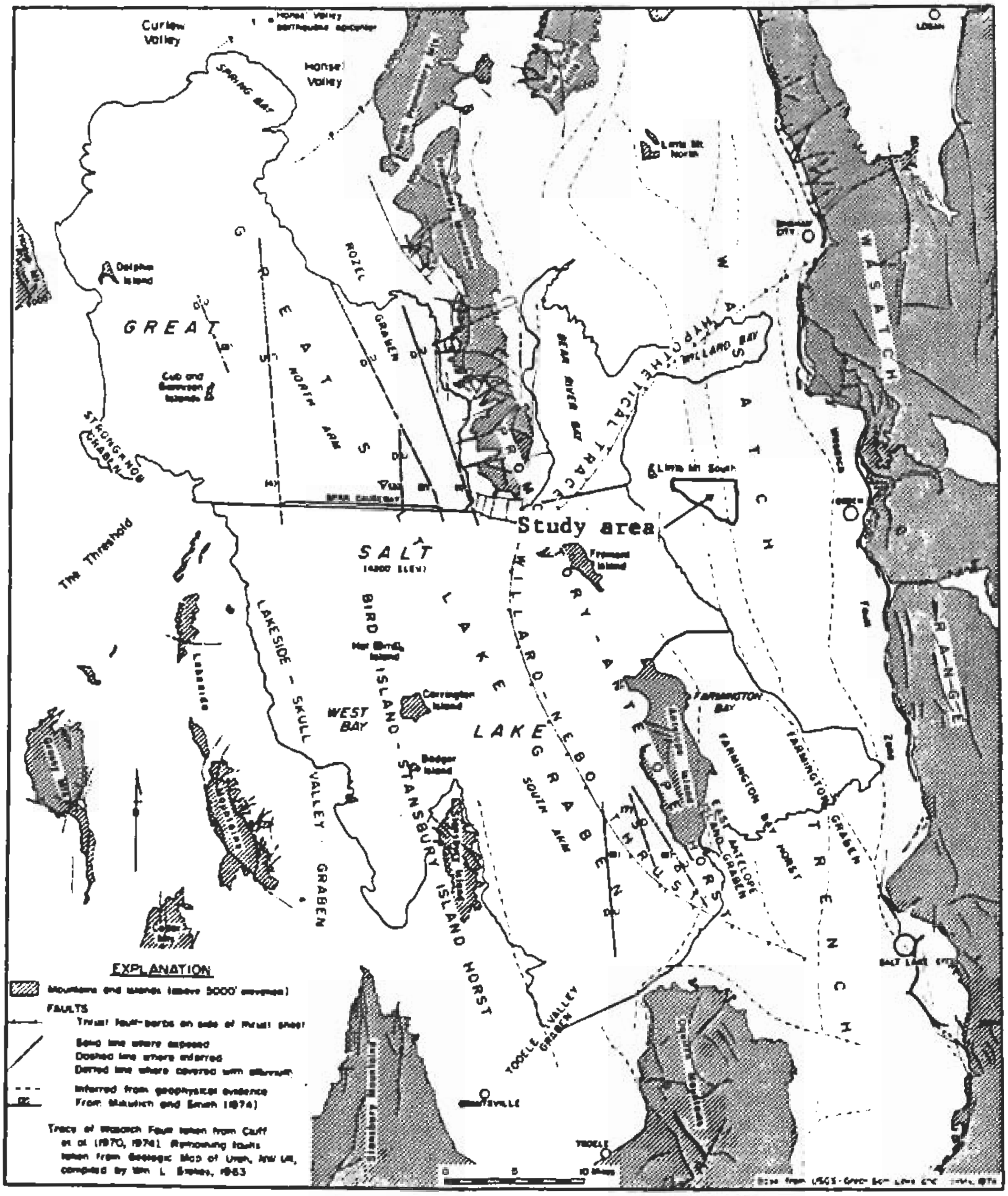


Figure 4. Proposed landfill site and surrounding major structural features and faults (after Stokes, 1980).

(Feth and others, 1966). At the landfill site, the Sunset aquifer averages approximately 265 feet below the surface and ranges in thickness from 50 to 250 feet (Feth and others, 1966). The deeper, Delta aquifer is generally encountered at depths ranging from 500 to 700 feet, attaining a thickness of 50 to 150 feet. This aquifer has not been mapped at the landfill site. However, wells drilled in sections 22, 23, 26, and 27 have encountered water at depths ranging from 257 to 607 feet, indicating the likely presence of the deeper aquifer. In addition, wells drilled within 200 horizontal feet of one another (in section 23) have tapped water reservoirs at 289 and 607 feet respectively.

The wide range of subsurface water depths shown by the deep, confined aquifers in the proposed landfill area suggests that the confining layers of the aquifers are somewhat permeable and that there is upward leakage of water. The upward movement of ground water results in discharge by springs, seeps, and evapotranspiration in areas near the Great Salt Lake (Bolke and Waddell, 1972). This condition is largely responsible for the abundance of small intermittent surface streams and ponds at the landfill site. However, retarded infiltration of precipitation by low permeability surface soils also contributes to pond formation. Upward leakage has been documented south of the proposed landfill, at the OBWMA (Feth and others, 1966), as well as north of the site near Little Mountain South, where upward water pressure has caused plastic liners in settling ponds owned by Western Zirconium, Inc. to rise (Kelley, 1985; Kelley, oral commun., Oct. 2, 1985).

As shown by test pit excavations, shallow unconfined water-table conditions exist in the primary disposal area of the proposed landfill and are undoubtedly widespread across the entire site. Although no data are available on directional flow of this water, topographic evidence suggests that subsurface flow is southwest, toward the OBWMA and North Fork of the Weber River. Shallow ground-water flow in the western section of the landfill is likely southeast, toward the Weber River. Soil surveys conducted by the U.S. Soil Conservation Service during the 1960s show shallow ground-water depths in the area ranging from 0 feet (water table at surface) in Lakeshore soils and surface depressions to a maximum of 5 feet in Leland soils which cover most of the landfill site (Erickson and Wilson, 1968). Test pits excavated in Leland soils (numbers 1, 3, and 4, appendix B) revealed slightly greater depths to water, ranging from 5.2 to 6.2 feet.

Shallow, unconfined ground-water levels in soils near the Great Salt Lake generally fluctuate in accordance with rising or falling lake levels. In addition, unconfined ground-water levels also fluctuate seasonally, typically reaching lowest levels during fall or winter. Test pit excavations took place in early October, when shallow ground-water levels were declining. Ground-water observed in the test pits (5.2 to 6.2 feet) therefore represents near-lowest levels achieved during the 1985-86 water year, and higher levels should be expected during spring and early summer of 1986.

Evidence for seasonal and/or annual fluctuations in shallow, unconfined ground-water levels is reflected in U.S. Soil Conservation Service soil surveys as well as in the test pit excavations. Erickson and Wilson (1968) report that distinct soil mottles are common in Leland soils below a depth of 2 feet. In the test pits, yellow, orange and rust-colored streaks, and mottles within 2.5 feet of the ground surface (test pits 3 and 4, appendix B) indicate formerly saturated conditions and a previously higher water table. Additionally, the great percentage of grayish color (gley) in the clay found at the bottom of test pit 2 is likely the result of iron and manganese reduction occurring under saturated conditions. The percentage of gley present in waterlogged materials has been found to be proportional to the duration of saturation and is indicative of the completeness by which reduced iron has been removed (Simonson and Boersma, 1972; Diers and Anderson, 1984). In addition, test pit soils showed a steady downward increase in moisture content starting at 1.7 to 2.0 feet below the surface (appendix B).

Flooding

At the proposed landfill, areas bordering the Weber River, OBWMA, and the North Fork of the Weber River lie in the 100-year flood hazard zone of the Weber River (Federal Emergency Management Agency, 1982; figure 5). This zone generally extends to the 4,212-foot contour, the approximate historic extent of the Great Salt Lake, but does not include many natural marsh areas and lowlands currently inundated with water. In addition to natural drainages, canals, and ponds shown on the topographic map (figures 2 and 5), other areas not on the map currently sustain ponded surface water. A private residence located just west of 7500 West Street near the center of section 26 was flooded during early October of 1985 (figure 5). A water pump and drain pipes were visible in the front yard of this property. Furthermore, approximately one year ago the Weber County Department of Roads excavated a channel to facilitate drainage from section 26 south into the North Fork of the Weber River (Max Hunter, oral commun., Oct. 2, 1985) (figure 5).

Heavier than average precipitation along the Wasatch Front during the 1981-82 and 1982-83 water years has caused the Great Salt Lake to rise and breach the levees surrounding the OBWMA. Flood waters from the lake entered the refuge and inundated the southern part of the proposed landfill to an elevation of approximately 4,205 feet in July of 1983, and to 4,209.95 feet in May of 1985 (Alder, 1985).

Figure 5 shows a "Beneficial Development Area" (BDA) which covers all land around the Great Salt Lake shore area up to 4,217 feet in elevation. This elevation corresponds to a topographic threshold where the main body of the lake merges with shallow depressions in the Great Salt Lake Desert and to documented, prehistoric (10,000 years ago to the present) lake level rises (Currey and others, 1984). Geological evidence has shown that the Great Salt Lake has reached or exceeded 4,217 feet at least twice during the past 3,000 years (Currey and others, 1984). The most recent rise to 4,217 feet is believed to have occurred between 1670 and 1700 A.D. Geochemical modeling indicates that the Great Salt Lake may have reached or exceeded 4,217 feet as many as five times in the last 500 years (Utah Division of Comprehensive Emergency Management, 1985). Based on this information, policymakers have determined that land below 4,217 feet elevation is at risk from periodic flooding of the Great Salt Lake and recommend that further development is incompatible with flooding and should be discouraged below that elevation (Utah Division of Comprehensive Emergency Management, 1985). As shown on figure 5, most of the proposed landfill lies below 4,217 feet elevation, including the primary disposal area. Although approximately one-quarter

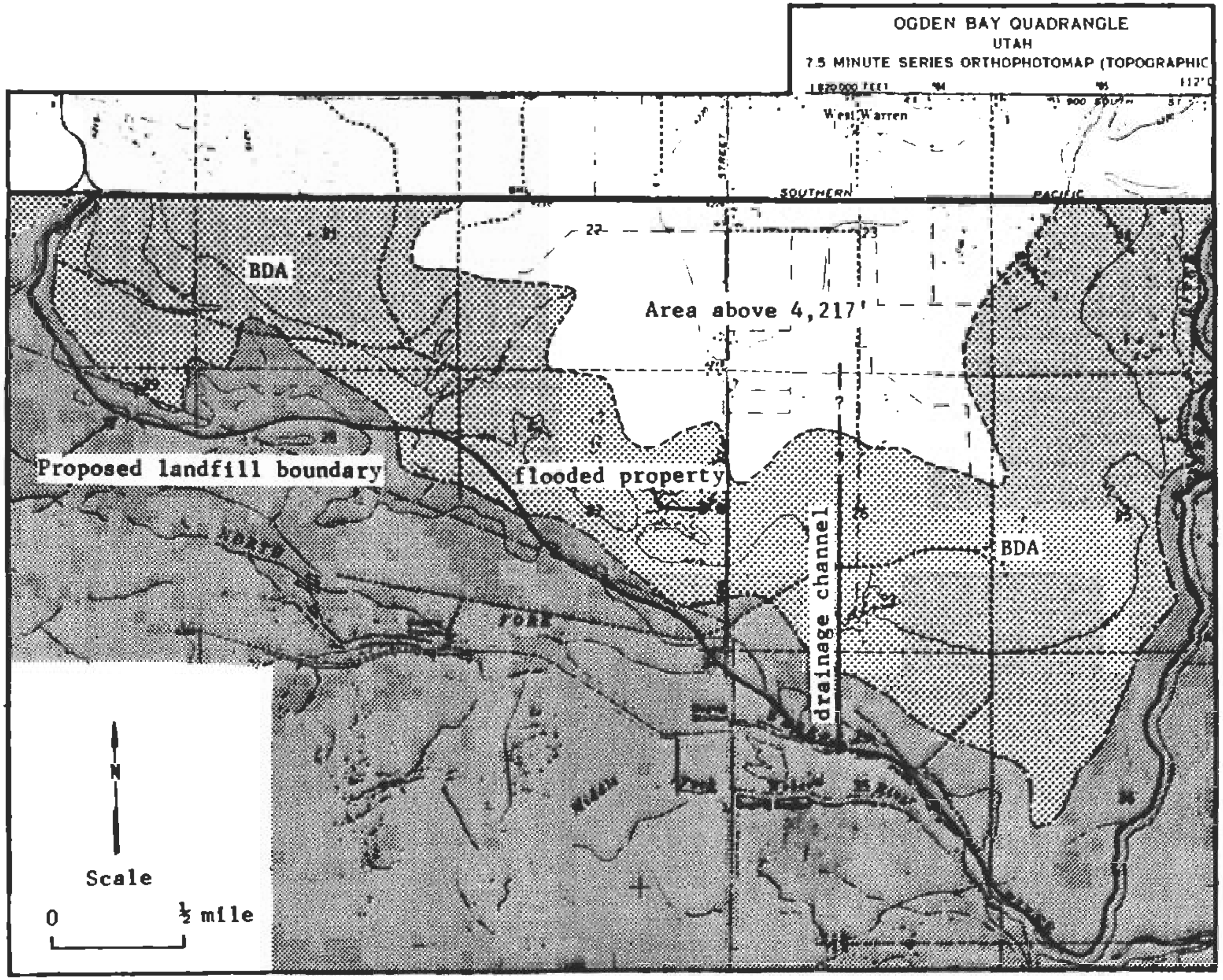


Figure 5. Proposed landfill site showing flooded property (•), drainage channel, Beneficial Development Area (BDA) of the Great Salt Lake (░), and 100-year flood hazard zone of the Weber River (▒).

(about 960 acres) of the total proposed site lies above 4,217 feet elevation, this land could be affected by rising unconfined ground-water levels should the Great Salt Lake again rise to 4,217 feet.

RESULTS AND DISCUSSION

According to Kelley (oral commun., Sept. 27, 1985), the proposed landfill will utilize on-site soils for cover material and for a 2-foot compacted foundation layer beneath individual refuse cells. Silty, and, to a lesser extent, fat clays make up the upper 3 to 4 feet of surface material in the proposed landfill area. Although clays characteristically exhibit low permeability and would limit infiltration when used for landfill cover, they also develop desiccation cracks which may allow rodents and others pests to penetrate the cover layer. Therefore, clays are considered less desirable than coarser soils for use as cover material (Brunner and Keller, 1972). Desiccation cracking was observed in a number of areas at the proposed site where vegetation was sparse or absent. In addition, the cohesive properties exhibited by clay soils make them difficult to work and compact when moist or wet.

Sand layers are present at shallow depths beneath the surface clay layers. In addition, the reddish-brown silty clay found from 1.7 to 3.8 feet below the surface shows increased sand content with depth (appendix B). The proposed compacted fill layer beneath the refuse cells could lose effectiveness as an impermeable barrier if the overlying clays are removed for cover material and the coarser, more pervious materials are used to construct the fill section. Because the thickness of the upper clay layer is limited, there is some doubt that a sufficient quantity of those soils are available on site for use both as cover material and pit liner.

The proposed landfill lies in an artesian ground-water discharge zone. There is virtually no chance that leachate (chemical and biological contaminants produced by interaction of refuse with water) would percolate down to the deep artesian aquifers beneath the site. However, it is possible that leachate could reach the shallow, unconfined ground water. The Utah State Department of Health Code of Solid Waste Disposal Regulations (1981) states that "at least 5 feet of separation between the bottom of disposal trenches and the highest ground-water elevation is desirable." Mottled soils indicating ground-water saturation were found within 2.5 feet of the ground surface, in two of the four test pits excavated, and were found to be common in Leland soils below a depth of 2 feet by Erickson and Wilson (1968). Other soils present at the site, but not surveyed in this study, also show evidence of high, unconfined ground water ranging from 0 to 5 feet below the ground surface (Erickson and Wilson, 1968). Given these facts, it is doubtful that a landfill at this site would meet ground-water separation recommendations.

Numerous surface ponds, man-made and natural drainage conduits, flooded areas, and marshes are found within the confines of the site. Although not stated in Department of Health regulations, landfill operations are prohibited within 100 feet of surface waters (Montague, Utah Division of Solid and Hazardous Waste Management, oral commun., Oct. 9, 1985). It is possible that leachate contaminants released to shallow ground water could reach these surface water bodies. In addition, the proposed site is in close proximity to the Weber River, OBWMA, and the Great Salt Lake. Surface water flow and shallow, unconfined ground-water flow migrate toward these waters.

Placing refuse above 4,215 feet elevation would probably prevent surface flooding of the landfill by a 100-year flood of the Weber River. However, documented rises of the Great Salt Lake to 4,217 feet and greater within prehistoric time show that most of the landfill site is at risk from periodic lake flooding. Moreover, it has been predicted that the lake could again rise to 4,217 feet (McKenzie and Gregor, 1985). If near average precipitation ensues in the future, the Great Salt Lake should decline from its current elevation. However, considering that the expected life of the proposed landfill has been estimated at 100 years, there is a realistic possibility that the Great Salt Lake could reach levels that would detrimentally affect the landfill, through direct surface flooding and/or rising of the shallow, unconfined ground-water table within this time frame. This possibility should be incorporated in planning for facilities located within close proximity of the lake.

The proposed landfill lies in Utah Seismic Safety Advisory Council zone U-4 and the Uniform Building Code seismic zone 3. The three inferred faults beneath the site show no evidence of surface rupture or recent movement. However, earthquakes produced along the active Wasatch fault zone to the east could adversely affect the landfill. In the event of a major earthquake, the site can expect to experience strong ground shaking, possibly resulting in soil liquefaction and lateral spreading. These conditions could cause cracking or rupture of refuse cells, permitting leachate contamination of shallow unconfined ground water and surface waters.

CONCLUSIONS

In response to Weber County Commissioner Roger F. Rawson's request for a site evaluation of the proposed landfill, and based on the results of this investigation and a review of Utah Department of Health Code of Solid Waste Disposal regulations (1981), it is concluded that the proposed site is poorly suited geologically for a landfill for the following reasons:

Shallow, unconfined ground water and numerous bodies of surface water make the site highly susceptible to leachate production and offer pathways for pollution migration. This may result in contaminants reaching the Weber River, Great Salt Lake, or the OBWMA, all of which are in close proximity to the site. High water-table conditions and the presence of sand horizons in the shallow subsurface make the potential for soil liquefaction and lateral spreading high. Both could occur in refuse cell disruption in the event of a major earthquake.

A substantial portion of the proposed landfill lies below 4,217 feet elevation, in a Beneficial Development Area, where proposals have been made to limit or restrict land development due to flood potential of the Great Salt Lake. The long-term nature of a landfill further increases the risk of flooding.

On-site, fine-grained soils would be marginal for use as cover material due to their potential for desiccation and limited workabilty when moist or wet. In addition, there may not be a sufficient volume of suitable soil available to meet requirements for both liner and cover purposes. A drilling program to determine compactability and availability of on-site soils was beyond the scope of this study.

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APPENDICES

Appendix A

Unified Soil Classification System

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION RETAINED ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS LARGER THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION PASSING NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT LESS THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS SMALLER THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT GREATER THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

APPENDIX B

Test Pit Soil Descriptions*

Test Pit 1

Subsurface Depth

0.0' - 1.0' Silty clay (CL/ML); topsoil, light brown, soft to firm, low plasticity, weakly indurated, moist; 5 percent fine sand.

1.0' - 2.3' Fat clay (CH); light brown to reddish brown, stiff, high plasticity, moderate to strongly indurated, dry; trace sand, caliche in top 7 inches.

2.3' - 3.8' Sandy lean clay (CL); light brown, soft to firm, low to medium plasticity, weak to moderately indurated, moist; 15 percent fine sand, sand content increases with depth.

3.8' - 6.2' Poorly graded sand (SP); brown, low density, nonplastic, subangular to subrounded, nonindurated, moist to saturated; 5 percent fines, distinct mottles below 4.9 feet.

Note: Ground water encountered at 6.2 feet below ground surface.

Test Pit 2

0.0' - 1.0' Lean clay (CL); topsoil, light brown, firm, low plasticity, weakly indurated, dry; 10 percent fine sand.

1.0' - 1.8' Fay clay (CH); white to reddish brown, very stiff, medium to high plasticity, moderate to strongly indurated, dry; trace sand, contains caliche stringers and nodules.

1.8' - 3.1' Lean clay (CL); reddish brown, soft to firm, low to medium plasticity, weakly indurated, moist to wet; 5 percent fine sand, sand content increases with depth.

3.1' - 6.2' Poorly graded sand (SP); brown, loose to low density, nonplastic, subangular to subrounded, nonindurated, moist to saturated; 5 percent fines, mottled to bottom of trench starting at 3.3 feet.

Note: Ground water encountered at 6.2 feet below ground surface; top of spoil pile contains a gray, mottled yellow lean clay (CL) derived below sand layer. Depth of clay layer unknown.

Test Pit 3

0.0' - 0.6' Silty clay (CL/ML); topsoil, light brown, firm, low plasticity, weakly indurated, dry; 5 percent fine sand.

0.6' - 1.7' Fat clay (CH); reddish brown, very stiff, high plasticity, moderate to strongly indurated, dry; trace sand, caliche stringers and nodules throughout.

1.7' - 3.8' Sandy lean clay (CL); reddish brown, soft to firm, low to medium plasticity, weakly indurated, moist to wet; 15 percent fine sand, sand content increases with depth, mottled to bottom of trench starting at 2.5 feet.

3.8' - 5.7' Poorly graded sand (SP); brown, loose to low density, nonplastic, subangular to subrounded, nonindurated, moist to saturated; 5 percent fines, fines increase toward top.

Note: Ground water encountered at 5.7 feet below ground surface.

Test Pit 4

0.0' - 0.7' Lean clay (CL); topsoil, grayish brown, firm, low plasticity, weakly indurated, moist; 5 percent fine sand.

0.7' - 2.0' Lean clay (CL); light brown to brown, firm to stiff, medium plasticity, moderately indurated, moist; caliche in upper 2 inches.

2.0' - 3.7' Lean clay (CL); reddish brown, soft to firm, low to medium plasticity, weakly indurated, moist to wet; 10 percent fine sand, mottled to bottom of trench starting at 2.5 feet.

3.7' - 5.2' Poorly graded sand with clay (SP-SC); brown, loose to low density, nonplastic, subangular to subrounded, nonindurated, wet to saturated; 10 percent fines.

Note: Ground water encountered at 5.2 feet below ground surface.

*Soils classified in accordance with procedures outlined in ASTM Standard D 2488-84, Description and Identification of Soils (Visual-Manual Procedure).

APPENDIX C

GLOSSARY

Aquifer: Stratum or zone below the surface of the earth capable of producing water as from a well.

Artesian: Refers to ground water under sufficient hydrostatic head to rise above the aquifer containing it.

Caliche: Secondary accumulation of calcium carbonate developed in soils at or near the surface.

Desiccation crack: Crack formed by shrinkage of clay or clayey beds in the course of drying.

Ephemeral stream: A stream that flows briefly only in direct response to precipitation, otherwise dry.

Gley: Soil mottling, caused by partial oxidation and reduction of its constituent ferric iron compounds, due to conditions of intermittant water saturation. Soil horizon is typically blue-gray in color.

Intermittant stream: A stream that flows only at certain times of the year, as when it receives water from springs or from some surface source.

Lateral spread: Limited-displacement ground failure associated with liquifaction or plastic flow.

Liquefaction: Transformation of a granular material from a solid state into a liquified state as a consequence of increased pore-water pressures.

Mottled soil: Sedimentary matrix irregularly marked with spots of different colors. Mottling in soils usually indicates poor aeration, lack of good drainage, and conditions of seasonal soil saturation.

Perennial stream: A stream that flows throughout the year.

Quaternary: Comprises all geologic time or rocks from approximately two million years ago to the present.